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High Power Picosecond Laser Pulse Recirculation

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We propose a novel high peak power ultrashort laser pulse re-circulation technique suitable for gamma-ray generation in Compton-backscattering sources. The two primary obstacles to higher average brightness and conversion efficiency of laser pulse energy to gamma-rays are the relatively small Compton scattering cross-section and the typically low repetition rates of Joule-class interaction lasers (10 Hz). Only a very small fraction (10^-10) of the available laser photons is converted to gamma-rays, while the bulk is discarded. To significantly reduce the average power requirements of the laser and increase the overall system efficiency, we can re-circulate laser light for repeated interactions.

Our pulse recirculation scheme is based on nonlinear frequency conversion, termed recirculation injection by nonlinear gating (RING). In the simplest implementation of this technique, the incident laser pulse at the fundamental frequency enters the resonator and is efficiently frequency doubled. The resonator mirrors are dichroic, coated to transmit the incident wavelength and reflect the 2nd harmonic light. The up-converted 2nd harmonic pulse becomes trapped inside the cavity. After many roundtrips, the laser pulse decays primarily due to Fresnel losses at the crystal faces and cavity mirrors.

The major advantage of the outlined recirculation scheme compared to active (electro-optic or acousto-optic) pulse switching is that the pulse traverses a significantly thinner optical material, thus minimizing the accumulated nonlinear phase; compared to passive, high-finesse resonators, our scheme is much more robust, as cavity tolerances are considerably relaxed from the interferometric precision characterizing passive systems.

The RING pulse recirculation cavity is currently being developed at Lawrence Livermore National Lab as part of the T-REX (Thomson-Radiated Extreme X-ray) project. A new class of tunable, monochromatic gamma-ray sources capable of operating at high peak and average brightness is currently being developed at LLNL for nuclear photo-science and applications. These novel systems are based on Compton scattering of laser photons by a high brightness relativistic electron beam produced by an rf photoinjector. Key technologies, basic scaling laws, and recent experimental results will be presented, along with an overview of future research and development directions.

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